

LETTER TO THE EDITOR

Pseudomagnitude Distances: Application to the Pleiades cluster

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ABSTRACT

The concept of pseudomagnitude was recently introduced by Chelli et al. (2016), to estimate apparent stellar diameters using a strictly observational methodology. Pseudomagnitudes are distance indicators, which have the remarkable property of being reddening free. In this study, we use Hipparcos parallax measurements to compute the mean absolute pseudomagnitudes of solar neighbourhood dwarf stars as a function of their spectral type. To illustrate the use of absolute pseudomagnitudes, we derive the distance moduli of 360 Pleiades stars and find that the centroid of their distribution is 5.715 ± 0.018 , corresponding to a distance of 139.0 ± 1.2 pc. We locate the subset of ~ 50 Pleiades stars observed by Hipparcos at a mean distance of 135.5 ± 3.7 pc, thus confirming the frequently reported anomaly in the Hipparcos measurements of these stars.

Key words. stars: distances – methods: observational – methods: data analysis – techniques: photometric

1. Introduction

In astrophysics, the calculation of interstellar extinction is a complex and recurring problem. For many objects, such as those buried in star-forming regions, unreddening the photometries is a difficult and demanding task. In the case of a star, the calculation of interstellar extinction requires a detailed knowledge of its luminosity class, spectral type, and intrinsic colors. That is a lot of parameters, not always available, whose robustness is often uncertain. This leads to the accumulation of errors, and makes it nearly impossible to attempt any massive statistical analysis.

We recently introduced the concept of pseudomagnitude for the calculation of the apparent size of stars, thus avoiding to deal with the problem of visual extinction (Chelli et al. 2014, 2016). This has allowed us to compile a catalogue of 453 000 angular diameters, with an accuracy of the order of 1% (2% systematic). Pseudomagnitudes are linear combinations of magnitudes constructed in such a way as to eliminate interstellar extinction. They are purely observational quantities that are unaffected by reddening effects, and can be applied to any type of object. As in the case of magnitudes, pseudomagnitudes are distance indicators, and absolute pseudomagnitudes, measured at a distance of 10 pc, are luminosity indicators.

Knowledge of the pseudomagnitudes and absolute pseudomagnitudes of stars allows their distance to be estimated. In the present study, we use the parallax measurements of Hipparcos (ESA 1997; van Leeuwen 2007) to calculate the mean absolute pseudomagnitude of field dwarf stars, as a function of their spectral type. As an example, we use this technique to determine the centroid of the distance distribution of 360 stars in the Pleiades cluster.

In section 2, we explain the concept of pseudomagnitudes. In section 3, we use distance filtered parallax measurements to calculate the mean absolute pseudomagnitudes (V,J), (V,H) and

(V,Ks) of dwarf stars, and the centroid of the distance distribution of our Pleiades stars is calculated and discussed in section 4.

2. Pseudomagnitudes

We define the pseudomagnitude $pm_{\{i,j\}}$ of an astrophysical object as follows:

$$pm_{\{i,j\}} = \frac{c_i m_j - c_j m_i}{c_i - c_j} \quad (1)$$

where m_i and m_j are the magnitudes measured in the photometric bands i and j , c_i (resp. c_j) is the ratio of the interstellar extinction coefficients R_i and R_v between band i and the visible band. We note that when one of the coefficients c_i or c_j tends to zero, the pseudomagnitude tends to the magnitude m_i or m_j . The pseudomagnitude is by construction a reddening free distance indicator. It can be written as:

$$pm_{\{i,j\}} = \frac{c_i M_j - c_j M_i}{c_i - c_j} + DM \quad (2)$$

where M_i and M_j are absolute magnitudes and DM is the distance modulus. At this stage, we define the absolute pseudomagnitude $PM_{\{i,j\}}$ as:

$$PM_{\{i,j\}} = \frac{c_i M_j - c_j M_i}{c_i - c_j} = pm_{\{i,j\}} - DM \quad (3)$$

The absolute pseudomagnitude is a reddening free luminosity indicator that can be computed very easily. This requires the knowledge of two magnitudes and a distance. On the other hand, once the mean absolute pseudomagnitude has been calculated for a group of stars sharing the same physical properties, the distance modulus of a star from the same group can be estimated with the knowledge of just two magnitudes.

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3. Absolute pseudomagnitudes of dwarf stars

For our calculations, we use Eqs. 1 and 3, with the second reduction of Hipparcos parallaxes (van Leeuwen 2007), the spectral type and the magnitude pairs (V,J), (V,H) and (V,Ks) provided by SIMBAD. We adopt the interstellar extinction coefficients determined by Fitzpatrick (1999), thus leading to the following expressions for the pseudomagnitudes:

$$\begin{aligned} pm_{\{V,J\}} &= 1.389 \times m_J - 0.389 \times m_V \\ pm_{\{V,H\}} &= 1.205 \times m_H - 0.205 \times m_V \\ pm_{\{V,Ks\}} &= 1.136 \times m_{Ks} - 0.136 \times m_V \end{aligned} \quad (4)$$

3.1. Hipparcos data

A priori, the absolute pseudomagnitude of a group of stars with the same spectral type and luminosity class should be constant as a function of distance. Figure 1a plots the pseudomagnitude (V,Ks) of Hipparcos class III and V stars with a spectral type K0 (3747 objects), as a function of their distance modulus. Figure 1b shows the absolute pseudomagnitude (V,Ks), with the dwarfs lying at the top and the giants lying at the bottom. For the same class of stars it is firstly constant, to within the limits resulting from noise, but beyond a certain distance it then appears to decrease. It is a mere artifact, due to the fact that below 10% noise, the inverse of the parallax begins to be numerically biased. In this example, 75% of the dwarfs and only 26% of the giants have a parallax noise smaller than 10%.

3.2. Practical absolute pseudomagnitude calculation

In order to calculate the mean absolute pseudomagnitudes of dwarf stars, we proceed as follows: a) we consider all of the stars in the Hipparcos catalogue having the same spectral type, with or without selecting their luminosity class, depending on the possible degree of confusion; b) we place a limit on the distance of the sample in order to minimize the influence of the numerical bias¹; c) since we do not control the astrophysical biases (see below), we assume that all of the objects are statistically equivalent, and adjust the fit of the absolute pseudomagnitude distribution to one, or even—in some cases—to two Gaussian functions.

This is a difficult operation because the absolute pseudomagnitude distribution is not always strictly Gaussian. In practice, stars from the same luminosity class and with the same spectral type often have stratified luminosities as a function of their distance. This phenomenon confirms what was already known, i.e. that for any given spectral type and class of luminosity, there are hidden sub-classes of stars with distinct physical properties. Although the absolute pseudomagnitudes would permit a detailed investigation of these physical properties, for the time being we do not have sufficient statistical information to implement such an analysis. This will become possible when the measurements provided by GAIA (de Bruijne 2012) become available.

Manual calculations were made for each spectral type, and were repeated several times on various samples of stars. These were based on the analysis of the pseudomagnitudes of approximately 6000 dwarf stars, distributed over 56 spectral sub-types. It corresponds to about 25% of the Hipparcos stars identified as dwarfs. 90% of the selected data have a parallax with less than 10% noise, 98% less than 20%. Figure 2 shows the mean abso-

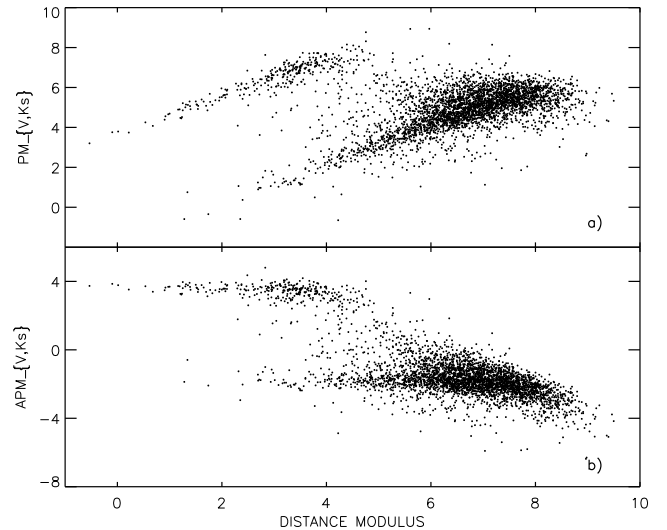


Fig. 1. a) (V,Ks) pseudomagnitudes of the 3747 Hipparcos K0 class III and V stars as a function of their distance modulus; b) Absolute (V,Ks) pseudomagnitudes of the same stars, with the dwarfs lying at the top and the giants lying at the bottom of this figure. The decrease of the pseudomagnitudes beyond a certain distance is an artefact due to numerical bias at low signal to noise ratio (see text).

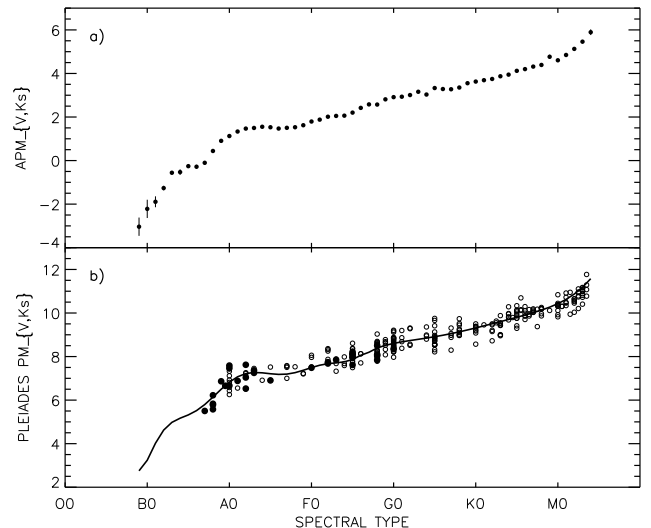


Fig. 2. a) Mean (V,Ks) absolute pseudomagnitudes of field dwarf stars as a function of spectral type, b) Open circles: (V,Ks) pseudomagnitudes of 280 Pleiades stars located at less than 0.84 mag (3 times the Gaussian dispersion of figure 3) from the Pleiades barycentric distance modulus. Hipparcos stars are identified with larger filled circles, superimposed our main sequence model shifted at the Pleiades distance.

lute pseudomagnitudes (V,Ks) of these dwarf stars as a function of their spectral types, ranging from O9 to M4.

The median statistical error on the mean absolute pseudomagnitudes is equal to 0.03 magnitudes, which corresponds to an error of 1.5% in terms of distance. For a given group of stars, the observed dispersions can be accounted for by the natural width of the group, which is increased by the influence of multiplicity, errors of magnitude, distance and classification. To a lesser extent, they also reflect the star's age or metallicity. We estimate, to within a factor of 2, that the systematic error on a correctly characterised single dwarf star is of the order of 0.05 magnitude.

Although pseudomagnitudes have many potential applications, the most immediate of these is the determination of the mean distance of a spatially concentrated group of stars, as for

¹ For example, in the case of the K0 stars of figure 1 b, this limit would be around $DM = 4$ for dwarves and $DM = 7$ for giants.

Refs	Method	N	DM / distance (pc)
1	Hipparcos first release	54	5.32 (0.05) / 115.9 (2.7)
2	Photometry	55	5.60 (0.04) / 131.8 (2.4)
3	Moving cluster	65	5.58 (0.18) / 130.6 (11.)
4	Ground parallax	9	5.58 (0.12) / 130.6 (7.0)
5	Photometry	30	5.61 (0.03) / 132.4 (1.8)
6	Hipparcos (Makarov)	54	5.55 (0.06) / 129.0 (3.3)
7	Binary	1	5.60 (0.03) / 131.8 (1.8)
8	Binary	1	5.65 (0.03) / 134.9 (1.9)
9	Binary	1	5.60 (0.07) / 131.8 (4.2)
10	HST parallax	10	5.66 (0.06) / 135.5 (3.7)
11	HST parallax	3	5.65 (0.05) / 134.9 (3.1)
12	Binary	1	5.72 (0.05) / 139.3 (3.2)
13	Hipparcos (van Leeuwen)	54	5.40 (0.03) / 120.2 (1.7)
14	VLBI	5	5.67 (0.02) / 136.2 (1.2)
15	Binary	1	5.61 (0.08) / 132.4 (4.9)
16	Photometry	120	5.62 (0.03) / 132.7 (1.8)
This work	Pseudomagnitude	360	5.715 (0.018) / 139.0 (1.2)

Table 1. Measured distances of Pleiades stars, errors are between parenthesis.

1: van Leeuwen & Evans (1998), 2: Pinsonneault et al. (1998), 3: Narayanan & Gould (1999), 4: Gatewood et al. (2000), 5: Stello & Nissen (2001), 6: Makarov (2002), 7: Munari et al. (2004), 8: Pan et al. (2004), 9: Zwahlen et al. (2004), 10: Johns-Krull & Anderson (2005), 11: Soderblom et al. (2005), 12: Southworth et al. (2005), 13: van Leeuwen (2009), 14: Melis et al. (2014), 15: David et al. (2016), 16: Kim et al. (2016); N: target number; DM: distance modulus.

example in the case of stellar clusters and galaxies. In the following section we calculate the centroid of the distance distribution of 360 stars in the Pleiades cluster, and whenever possible compare our results with those obtained by other authors.

4. Pseudomagnitude distance of the Pleiades

The Pleiades is one of the most commonly observed young open clusters, and the properties of its stars provide a *de facto* definition of the properties of main sequence stars at age zero. Numerous studies continue to be published regarding the census of this cluster's coeval stars, and the highest possible accuracy is needed in their distance determinations in order to test the models of stellar structure and evolution. The pseudomagnitude method can be applied to all of the stars in this cluster, for which the spectral type and at least one pair of magnitudes is known. It is perfectly adapted to the calculation of the cluster's mean distance, and could even be sufficient for the accurate evaluation of the individual distances of these stars (see section 4.3).

4.1. On the Pleiades distance controversy

Whereas an history of distance estimations of the Pleiades cluster can be found in An et al. (2007) and Melis et al. (2014), Table 1 provides a summary of the measurements published in the last 20 years. Various methods have been used. Excluding Hipparcos, the other direct distance measurements (ground and spaceborne parallaxes, binaries, VLBI) have relied on the analysis of a total of ≈ 30 stars, and position the Pleiades at a distance between 130 and 139 pc. The indirect photometric methods were applied on a total of ≈ 120 stars and have positioned the cluster at a distance of 132 pc. In contrast, the mean distance of 54 Pleiades stars of spectral types B, A and F by Hipparcos (van Leeuwen 2009) lead to the controversial distance of 120.2 ± 1.7 pc, which is indeed markedly lower (by 10%) than all other measurements.

It should be recalled that the Pleiades cluster probably contains more than one thousand stars. When projected onto the sky, it extends over a distance of the order of 10 to 20 pc, and it would be reasonable to assume that the Pleiades has a similar size along

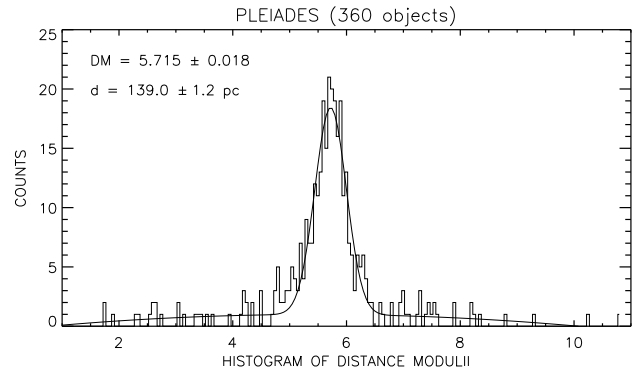


Fig. 3. Distance moduli distribution for 360 Pleiades stars, fitted by a Gaussian distribution plus second degree polynomial. The Gaussian dispersion (0.28 mag) is dominated by spectral classifications errors.

its line of sight when viewed from Earth. Under these conditions, the distances measured on a few, or even a few tens of objects, with an accuracy much better than the cluster's expected size, are representative of these objects distances only. In view of the size of this cluster, it could well be possible to find star concentrations at distances of the order of 15 pc from one another. The controversy does not have as much to do with the so-called distance of the Pleiades cluster², as with the mean distance of the 54-odd stars used in the Hipparcos estimate.

It is difficult to compare various distance measurements, as they are based on generally small and generally disjoint samples of stars. The Hipparcos sample was not used by other independent distance estimations, it was only reused in new attempts to refine the Hipparcos reduction, first by Makarov (2002) which led to a distance of 129.0 ± 3.3 pc, and then by van Leeuwen (2009), who determined a value of only 120.2 ± 1.7 pc. We note that in view of their uncertainties, these two distance estimations are only marginally (2.4σ) different.

Our absolute pseudomagnitude calibration allows us to evaluate the distance of any sample of stars. In the following section, we calculate the distance of 360 Pleiades stars, as well as that of the Hipparcos sample.

4.2. Distance of 360 Pleiades stars

In this section, we assume that Pleiades stars have, at the same spectral types, the same pseudomagnitudes (V,J), (V,H) and (V,Ks) that field dwarfs. Significant differences occur for cool stars somewhere within the M spectral class. Our sample of Pleiades stars was obtained from a total of 3721 stars associated with the “M45” identifier in the Simbad database. After filtering (multiplicity, variability, etc.), a total of 512 stars remained, of which only 360 had the required information for the calculation of their distance. As the Pleiades cluster is very young, in order to increase the size of our sample, we assumed all of the selected stars to be of luminosity class V. As the pseudomagnitude is sensitive to the luminosity class, any non-dwarf star will contribute to the broadening of the distance distribution, or will get a distance very different to that of the cluster and will thus be excluded from the analysis. We did not try to perform filtering for membership, non members will form a diffuse background that is taken into account in our statistical modeling.

² We observe that, given the currently achievable precision on an individual star distance and the size of the cluster compared to its distance ($\approx 10\%$), the concept of “Pleiades distance” is bound to loose its intended meaning.

The adopted distance modulus of each object is the average of the distance moduli computed from the photometric pairs (V,J), (V,H) and (V,Ks), and its error is the dispersion of the three estimates. The (V,Ks) pseudomagnitudes of our sample, outliers excluded, are shown in Figure 2b as a function of the spectral type. It is not a classical color-magnitude diagram. The observed dispersions per spectral type, 0.2 to 0.4 magnitude, are not imposed by the physics of the cluster but by spectral classifications errors, which is probably the limiting noise of our present approach. We fit the resulting distance modulus distribution by a Gaussian plus a second degree polynomial, see Figure 3. The centre of the Gaussian function provides the barycentre of the distance moduli of the 360 stars studied, i.e. 5.715 ± 0.018 , which corresponds to a distance of 139.0 ± 1.2 pc. Although this comparison is somewhat risky, in view of the small samples used previously, our distance calculation is globally in agreement with most estimations, but tends to position the cluster at the high end of measured “distances”.

What of the stars measured by Hipparcos? We have all of the information needed to characterise 44 of the 54 stars given in the list of Makarov (2002). The distribution of their distance moduli exhibits two maxima, at approximately 5.4 and 5.7, a possible indication of sub-clustering. A gaussian fit of this distribution leads to a mean distance modulus of 5.66 ± 0.06 , i.e. a distance of 135.5 ± 3.7 pc, respectively 1.3σ and 3.8σ above Makarov (2002) and van Leeuwen (2009) estimates. Our result tends to confirm that on average Hipparcos distances of these stars are underestimated. Soon we will have the answer on who is right or who is wrong. But the answer probably will not be as simple as yes or no.

However, the baby should not be thrown out with the bathwater, since all of our distance moduli were obtained using absolute pseudomagnitudes derived from correctly distance-filtered Hipparcos parallax measurements. The fact that we obtain a barycentric distance that is compatible (and probably more accurate in terms of defining the cluster’s centroid, as a consequence of the much greater sample size) with distances measured from the ground, together with the fact that we are able to apparently correct the same controversial Hipparcos measurements, indicates that Hipparcos parallaxes at large are robust.

4.3. Distance to the VLBI stars

Among recent distance measurements, those of Melis et al. (2014) determined by VLBI are the most accurate. As they make it possible to test the robustness of our pseudomagnitude estimations, we calculate the distance of 6 of the 10 stars scheduled for VLBI observation by Melis et al. (2013) (the 4 others are either not single dwarfs or lacking spectral type information). Table 2 summarises our predicted distances. For the two stars in common with Melis et al. (2014), the agreement between VLBI and pseudomagnitude distances is remarkable, with relative differences of 1% (0.5σ) and 4% (1.6σ).

5. Conclusion

Pseudomagnitudes are remarkable distance indicators, since they are free of interstellar reddening effects. We have calculated the mean absolute pseudomagnitudes of field dwarfs from O9 to M4, based on the Hipparcos parallax measurements of approximately 6000 stars, allowing us to estimate the distance of 360 Pleiades stars. We position the centroid of these stars at 139.0 ± 1.2 pc, and we confirm that the Pleiades stellar distances measured by Hipparcos are on average underestimated by 10%.

HII	SpT	PMD (pc)	VLBI distance (pc) ⁽¹⁾
75	G7	136.2 (3.6)	
253	G1	143.7 (2.1)	
625	G5	137.0 (2.4)	138.4 (1.1)
1136	G7	141.0 (3.3)	135.5 (0.6)
1883	K2	139.0 (1.4)	
2244	K2	145.1 (2.1)	

Table 2. Pseudomagnitude distance (PMD) of 6 Pleiades stars of the Melis et al. (2013) list. (1) Melis et al. (2014)

ESA’s recently launched GAIA mission will make it possible to accurately determine the fine structure of absolute pseudomagnitudes, their natural width, and the influence of various parameters such as age and metallicity. It will be possible to calibrate these very accurately, in several different optical bands. But already, our initial results obtained with the Pleiades cluster, together with their comparison with VLBI measurements, are very encouraging. This technique is purely observational, direct and simple to implement, since it needs the knowledge of only the spectral type, two magnitudes and the corresponding absolute pseudomagnitude.

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³ available at <http://www.starlink.ac.uk/topcat/>

Table 3. Pseudomagnitude distance (PMD) and errors (pc) of 360 Pleiades stars. Names are those returned by CDS when searching for “M45”. The PMDs are the mean of the 3 distances (V,J), (V,H), (V,K). The error is the dispersion of those distances. Only the subset of 360 stars for which our method is applicable are reported.

Name	PMD (pc)	Error (pc)
BD+17 558	179.47	11.01
Cl* Melotte 22 MSK 211	144.95	1.01
HD 23326	147.74	.54
* 22 Tau	114.57	1.61
HD 23195	140.02	1.66
HD 282960	126.31	.90
V* V1084 Tau	114.71	2.52
V* V623 Tau	160.84	.03
Cl* Melotte 22 HII 1593	142.55	1.99
Cl* Melotte 22 DH 507	132.47	1.48
V* V1272 Tau	143.68	2.14
2MASS J03461174+2437203	151.53	2.01
V* V1288 Tau	136.17	3.57
Cl* Melotte 22 DH 290	138.06	1.91
V* V1046 Tau	119.18	2.65
BD+23 521	134.79	.80
HD 23568	142.38	.56
Cl* Melotte 22 SK 671	115.15	1.00
BD+22 521	153.75	.08
HD 282965	117.26	3.60
V* V540 Tau	157.70	.38
Cl* Melotte 22 HII 974	137.64	1.12
HD 24087	114.78	2.25
V* LT Tau	99.67	2.60
V* V1187 Tau	156.35	1.82
Cl* Melotte 22 DH 131	116.10	1.08
V* V815 Tau	139.99	.88
Cl* Melotte 22 MSK 184	141.33	.66
BD+26 592	126.75	1.74
HD 23312	151.37	1.27
V* MS Tau	144.56	1.64
HD 23872	139.56	1.74
BD+22 574	158.92	1.14
* q Tau	92.06	2.07
Cl* Melotte 22 DH 525	137.69	.54
BD+22 548	126.47	1.71
Cl* Melotte 22 SRS 80212	128.48	3.10
V* V715 Tau	136.53	.90
* 21 Tau	117.65	.95
Cl* Melotte 22 SRS 52852	124.27	.91
HD 282967	117.87	2.25
HD 23464	67.20	1.05
HD 23061	150.41	.67
V* LV Tau	125.90	.46
V* V642 Tau	106.17	1.26
HD 282971	149.25	.96
HD 23732	131.41	1.08
Cl* Melotte 22 SK 775	175.25	.23
V* V814 Tau	136.98	.19
HD 283046	193.01	2.21
Cl* Melotte 22 MSH 175	134.88	1.80
HD 283132	134.70	2.24
TYC 1799-272-1	144.22	2.83
HD 23873	139.10	1.51
TYC 1803-1156-1	133.77	1.33
Cl* Melotte 22 HII 1110	134.36	1.49
2E 857	133.60	4.08

Table 3. continued.

Name	PMD (pc)	Error (pc)
BD+23 527	150.35	.08
V* V497 Tau	144.71	1.23
* 27 Tau	46.63	.54
V* V811 Tau	137.04	2.42
Cl* Melotte 22 DH 212	128.57	1.96
HD 24194	126.86	.60
V* V641 Tau	143.41	2.07
Cl* Melotte 22 DH 293	157.91	1.91
BD+21 504	120.15	2.06
Cl* Melotte 22 DH 267	112.64	2.81
V* V1274 Tau	47.75	.69
2MASS J03441466+2406065	91.95	3.08
HD 23763	100.51	1.10
HD 282975	98.92	.81
Cl* Melotte 22 MSK 74	140.34	4.94
Cl* Melotte 22 SK 40	162.67	.75
V* OS Tau	115.60	3.38
Cl* Melotte 22 DH 108	123.33	2.93
Cl* Melotte 22 DH 184	141.75	1.00
V* V1010 Tau	133.73	.54
TYC 1803-1351-1	98.47	.85
V* V1228 Tau	117.20	.61
V* V644 Tau	139.39	2.44
HD 23608	113.83	1.24
V* V378 Tau	160.17	.64
Cl* Melotte 22 SK 488	133.65	3.45
Cl* Melotte 22 HHJ 437	207.91	2.11
HD 23924	161.74	2.23
SAO 76387	185.78	1.88
Cl* Melotte 22 DH 143	134.44	.87
V* V476 Tau	97.93	.16
2MASS J03493653+2417460	179.22	1.55
Cl* Melotte 22 DH 436	146.34	.51
Cl* Melotte 22 DH 562	127.81	3.78
HD 23387	108.94	1.44
V* V446 Tau	143.41	2.00
HD 283420	110.87	.51
BD+22 553	169.93	2.09
HD 282958	126.44	1.88
Cl* Melotte 22 SK 754	150.36	3.04
CCDM J03481+2409AB	111.98	1.84
V* V703 Tau	133.83	.41
* 16 Tau	130.34	1.47
V* V1065 Tau	140.96	3.31
Cl* Melotte 22 SSHJ G315	165.54	1.70
V* V664 Tau	145.15	3.11
Cl* Melotte 22 HII 102	122.18	1.24
HD 24463	114.36	1.94
HD 282973	117.76	3.80
V* V727 Tau	96.25	.99
V* V1224 Tau	148.57	5.47
BD+23 472	150.45	1.28
BD+22 624	143.38	.79
HD 23352	164.74	3.79
Cl* Melotte 22 DH 153	93.01	2.47
V* V855 Tau	114.57	3.98
Cl* Melotte 22 DH 875	155.64	1.71
HD 23327	128.01	.71
* eta Tau	41.17	.44
Cl* Melotte 22 DH 349	148.80	.71
BD+22 552	167.99	.44

Table 3. continued.

Name	PMD (pc)	Error (pc)
HD 23975	113.28	1.96
Cl* Melotte 22 DH 603	133.62	1.12
Cl* Melotte 22 DH 734	177.77	1.85
HD 23886	154.19	1.30
HD 22444	89.73	1.89
V* V700 Tau	129.73	.45
Cl* Melotte 22 SRS 68435	184.05	.18
BD+25 555	148.92	2.95
V* V647 Tau	160.26	2.34
Cl* Melotte 22 DH 486	139.59	2.71
Cl* Melotte 22 SK 709	138.63	1.28
HD 23935	123.82	3.02
Cl* Melotte 22 MSH 82	161.58	1.22
V* V810 Tau	176.53	8.31
BD+23 551	140.10	2.78
V* V650 Tau	142.39	1.35
V* V652 Tau	103.63	.37
V* V966 Tau	141.91	1.82
TYC 1799-102-1	154.68	1.44
V* V813 Tau	195.53	6.05
* 17 Tau	69.10	1.15
V* LR Tau	33.04	.61
HD 23514	146.05	2.29
V* V812 Tau	131.48	.75
Cl* Melotte 22 LLP 15	140.66	1.43
V* V1041 Tau	131.69	2.10
UCAC2 40300217	109.71	1.29
Cl* Melotte 22 DH 421	106.65	.82
V* V1045 Tau	162.03	2.77
HD 23351	133.79	1.26
Cl* Melotte 22 DH 417	149.93	.80
Cl* Melotte 22 DH 462	140.35	.28
BD+20 672	121.96	1.68
V* V1283 Tau	128.04	2.36
V* V1210 Tau	139.54	1.26
Cl* Melotte 22 DH 456	162.22	2.37
* 20 Tau	52.64	1.86
V* PR Tau	149.08	1.09
Cl* Melotte 22 DH 271	133.39	2.75
Cl* Melotte 22 MSK 44	161.22	3.76
V* V643 Tau	110.74	.65
NAME 1RXS J034412.1+240200SE	135.08	2.99
V* OU Tau	151.78	3.78
V* V1170 Tau	133.91	2.06
V* KO Tau	118.00	5.35
HD 23511	148.60	3.30
V* V1175 Tau	148.48	3.71
Cl* Melotte 22 K 78	135.25	3.82
V* V382 Tau	117.31	1.33
V* V534 Tau	130.10	1.40
V* V660 Tau	139.00	1.43
Cl* Melotte 22 LLP 28	103.66	2.49
V* V1090 Tau	153.17	3.79
V* V371 Tau	94.09	1.18
V* V535 Tau	145.83	.36
V* V1169 Tau	153.65	2.73
V* V1171 Tau	310.83	11.59
V* V969 Tau	90.48	1.03
Cl* Melotte 22 HII 2209	151.73	3.20
HD 282954	133.28	.95
HD 23513	148.86	1.06

Table 3. continued.

Name	PMD (pc)	Error (pc)
HR 1183	142.46	.91
V* V1282 Tau	101.59	.96
HD 23489	130.18	2.37
HD 24665	116.06	1.25
BD+27 545	159.50	1.79
HD 23512	142.27	1.43
HD 23791	157.58	4.36
V* V1176 Tau	100.40	1.12
V* V1193 Tau	143.70	.66
HD 23584	139.06	2.88
HD 23598	134.56	1.77
Cl* Melotte 22 DH 730	149.09	2.56
V* V963 Tau	131.11	1.08
V* V1173 Tau	141.24	1.39
HD 23912	146.43	.76
HD 23158	148.63	.53
HD 23361	147.82	1.48
HD 23409	143.08	1.41
V* V1172 Tau	143.41	2.13
V* V816 Tau	152.73	4.91
V* V545 Tau	151.08	1.32
V* V844 Tau	163.42	2.94
HD 23479	125.96	.22
HD 23733	131.23	.71
HD 23632	126.62	4.35
* 18 Tau	119.70	1.26
HD 23863	157.47	.78
HD 23778	127.42	.27
V* V785 Tau	142.26	.94
V* V1174 Tau	189.61	3.19
HD 282952	159.92	6.83
BD+23 513	128.94	2.07
HD 24076	102.17	.69
HD 23269	127.53	3.76
* 24 Tau	104.48	1.15
V* II Tau	29.56	.22
BD+19 587	143.25	.63
* 28 Tau	82.99	3.27
HD 23610	179.87	1.89
HD 23948	171.39	1.86
HD 24132	138.60	1.68
BD+21 508	153.17	2.71
V* V370 Tau	159.63	.39
V* V518 Tau	184.17	3.43
V* V677 Tau	136.39	1.51
* 23 Tau	78.99	.69
HD 23375	136.76	2.21
HD 23631	156.43	1.05
Cl* Melotte 22 DH 304	150.95	1.83
Cl* Melotte 22 MSH 74	146.85	1.10
HR 1172	106.54	.82
Cl* Melotte 22 MSK 140	137.55	3.96
GJ 3219 A	29.19	.21
V* V452 Tau	87.67	1.61
BD+20 628	213.30	1.91
BD+23 514	143.40	3.25
HD 283117	129.62	1.59
V* V539 Tau	91.22	.18
HD 283031	739.44	19.91
BD+24 501	326.31	1.98
Wolf 1260	89.06	2.21

Table 3. continued.

Name	PMD (pc)	Error (pc)
V* CL Ari	176.87	2.72
V* V1085 Tau	182.90	.50
Cl* Melotte 22 SK 792	325.49	1.26
HD 282926	582.29	16.02
BD+24 470	453.13	9.08
HD 283222	110.23	1.20
V* V1227 Tau	10.51	.72
V* V613 Tau	123.89	1.72
V* V372 Tau	101.83	1.31
HD 23157	118.59	.60
TYC 1807-1756-1	183.99	3.55
BD+24 456	436.57	6.13
HD 22693	189.20	5.42
HD 283079	177.62	1.76
TYC 1805-572-1	248.78	1.59
HD 282998	142.82	1.77
Cl* Melotte 22 SK 646	164.77	.89
HD 24105	73.22	3.48
V* V349 Tau	112.88	2.23
V* V638 Tau	142.50	.79
BD+26 580	102.94	.85
Cl* Melotte 22 WCZ 141	1119.62	18.23
HD 283044	42.57	.80
V* V532 Tau	143.20	2.38
V* SZ Ari	304.14	10.70
HD 283058	62.35	1.11
V* LO Tau	118.57	2.20
V* V468 Tau	179.05	2.66
V* PP Tau	143.72	2.30
GJ 3227	24.03	.14
V* V338 Tau	124.47	1.43
V* V377 Tau	137.61	1.27
Cl* Melotte 22 DH 368	170.68	4.08
HD 282942	49.30	.75
BD+25 604	125.24	1.53
V* CG Ari	80.46	1.54
GJ 3240	22.47	.33
V* V561 Tau	137.48	2.05
V* EQ Tau	178.99	1.32
V* QS Tau	1383.72	90.87
StKM 1-406b	53.58	.32
V* V361 Tau	131.28	1.51
LP 355-27	33.41	.75
HD 23431	260.15	1.28
BD+24 479	340.82	7.25
V* V358 Tau	133.71	2.42
V* V366 Tau	101.41	1.12
BD+18 541	121.01	1.33
HD 283014	437.72	3.74
BD+19 589	107.11	4.69
BD+26 586	314.70	1.70
BD+26 553	283.42	3.47
BD+17 637	228.69	5.36
HD 23410	130.63	4.62
HD 23289	142.45	1.22
V* V679 Tau	88.24	1.01
V* V502 Tau	144.40	.95
V* V357 Tau	149.65	2.15
BD+20 549	154.47	1.80
HD 283139	125.47	1.44
BD+23 433	285.71	2.96

Table 3. continued.

Name	PMD (pc)	Error (pc)
V* FL Tau	113.78	1.62
HD 285234	145.61	1.23
Cl* Melotte 22 DH 504	107.90	1.18
HD 282972	154.18	6.75
V* V1229 Tau	122.60	.45
TYC 1787-384-1	247.45	4.40
HD 283038	230.53	2.11
V* V380 Tau	126.91	1.41
V* V470 Tau	154.77	2.24
V* V354 Tau	128.81	2.72
BD+20 626	109.33	2.22
BPM 85549	68.12	.56
2MASS J03235551+2339273	65.16	3.11
BD+16 455	304.16	1.27
BD+19 594	150.76	2.43
V* V739 Tau	130.51	3.61
V* V376 Tau	154.42	3.50
BD+19 607p	179.56	2.80
BD+25 592	246.77	4.79
2MASS J03273245+2554003	73.26	1.41
BD+22 512	32.64	.45
HD 283032	423.77	8.11
HD 24344	378.83	1.53
HD 283055	161.93	2.79
V* V1286 Tau	126.09	.56
NAME 1RXS J034412.1+240200NW	196.43	15.41
HD 285243	93.75	.88
HD 283006	141.52	1.05
TYC 1798-1002-1	125.91	2.30
BD+25 539	170.07	1.61
LH98 95	119.66	1.10
V* CU Tau	260.27	6.18
BD+20 565	253.31	2.43
Cl* Melotte 22 MSK 100	117.43	5.48
V* V399 Tau	129.12	.78
GJ 3239	35.30	.73
StKM 1-417	89.95	1.17
2MASS J03181744+1824202	72.59	1.94
2MASS J03414386+1824061	39.48	.55
BD+25 610	129.16	2.21
BD+20 594	128.88	.58
HD 282955	383.91	3.69
HD 283036	282.28	6.21
GJ 3225	32.09	.82
BD+22 468	181.70	1.81
HD 24355	303.59	2.30
GJ 140 C	21.81	.23
BD+25 572	68.08	1.86
TYC 1805-890-1	155.43	.13
HD 22139	137.84	1.69
V* QX Tau	123.85	.51
V* V343 Tau	146.99	2.75
HD 24088	214.86	3.73
BD+23 538B	93.64	2.68
2MASS J03164389+1923041	177.42	5.74
V* CK Ari	33.27	.16
HD 282928	246.31	.86
HD 282990	150.14	2.82
HD 23964C	113.88	.93